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# CHEMICAL CONTROL OF CANADA THISTLE (CIRSIUM ARVENSE (L.) SCOP.) IN CREEPING RED FESCUE AND TIMOTHY SEED CROPS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Chemical Control of Canada Thistle (*Cirsium arvense* (L.) Scop.) in Creeping Red Fescue and Timothy Seed Crops submitted by Albert Gallagher in partial fulfilment of the requirements for the degree of Master of Science.

## ABSTRACT

Field experiments throughout Northern Alberta established picloram (4-amino-3,5,6-trichloropicolinic acid) as an excellent herbicide for the control of Canada thistle (*Cirsium arvense* (L.) Scop.). Rates of 8 to 12 oz/A were sufficient to consistently reduce thistle stands under all conditions.

Preplant herbicide treatments were tolerated by creeping red fescue (*Festuca rubra* L.) and timothy (*Phleum pratense* L.) if one growing season elapsed between treatments and planting of the grasses. Seeding of the grasses three weeks following herbicide application resulted in reduced grass stands and dry matter production in several instances.

Seedling stands of creeping red fescue treated at the 1- to 5-tiller stage grew and developed better where thistle control was provided by single applications of picloram at 4,8, and 12 oz/A or dicamba at 24 oz/A. Fertile tiller production was increased substantially in plants selected from plots treated in the field with 4 and 12 oz/A of picloram at the 3- to 5-tiller stage, and transferred to a growth chamber.

Seed production of timothy was not affected by 2 to 12 oz/A of picloram when applied at several growth stages. Dicamba and 2,4-D treatments were tolerated best at the post-flowering stage of growth.

Creeping red fescue seed production was reduced by most herbicide treatments applied at 10 per cent anthesis in 1969. Plants receiving 8 and 12 oz/A of picloram in 1969 were prostrate and seed head numbers were reduced in 1970.

In no instance did herbicide treatment result in more than a 9.4 per cent reduction in percentage germination of the seed from either grass species when compared to the untreated check. Dicamba applied on timothy two weeks after the peak flowering period did not significantly reduce the seed germination but seedlings produced were prostrate and bent. Picloram at 2 oz/A had no effect on seed germination irrespective of the growth stage of the plants at treatment time.

In greenhouse experiments with picloram and dicamba-treated soil, creeping red fescue germinated and emerged more readily than did timothy. Surviving timothy plants grew and developed more readily, however, than did creeping red fescue plants.

Dissipation of dicamba under field conditions was complete by the end of one growing season. Picloram soil residues which were phytotoxic to cucumbers were detected at all locations and at most rates of application after more than one growing season had elapsed. Dissipation of picloram was greatest at the St. Albert plot and this was attributed to the high organic matter content of the soil.

The use of picloram or dicamba for thistle control in grass seed fields is feasible. Picloram applied to actively growing thistles in the bud stage on a spot application basis and prior to seeding at rates of 4 to 8 oz/A followed three to four weeks later by intensive cultivation is recommended. Thistle regrowth can be treated when seedling grasses are past the three to four-leaf stage with a mixture of 4 oz/A of dicamba and 8 oz/A of MCPA amine or 2,4-D amine.

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# INTRODUCTION

Forage seed crops provide a valuable alternative in agricultural production where favourable climatic conditions prevail. Alberta has the varied climatic conditions and land resources which favour a diversified agricultural base. As a result the Canadian forage seed industry has become concentrated in Alberta.

The following table of 1969 production figures gives an indication of the size and importance of the forage seed industry.

Table 1 Production (1,000 lbs.) of alfalfa, clover and grass seeds in Canada and Alberta during the 1969 crop year.

| Seed Crop | Canada | Alberta |
|---|---|---|
| Creeping red fescue | 11,500 | 10,000 |
| Timothy | 10,649 | 750 |
| Bromegrass | 2,684 | 1,835 |
| Crested wheat grass | 1,229 | 750 |
| Meadow fescue | 1,582 | 100 |
| Alfalfa | 1,064 | 550 |
| Red clover, double cut | 5,385 | 150 |
| Red clover, single cut | 4,772 | 2,700 |
| Alsike clover | 6,145 | 4,850 |
| Sweet clover | 20,155 | 6,000 |
| Total | 65,165 | 27,685 |

[a] Final Seed Report, Plant Products Division, Production and Marketing Branch, Canada Department of Agriculture, Ottawa, May 12, 1970.

The figures show that Alberta was responsible for 43 percent of the total Canadian forage seed production in 1969.

Weeds can seriously reduce forage seed crop yields since they compete for available nutrients and light. Losses are also incurred because of difficulties with the threshing and cleaning of a weedy crop. Weed seeds can make a large contribution to the total dockage of the crop and seed certification requirements may not be met if established weed seed tolerances are exceeded.

Canada thistle (*Cirsium arvense* (L.) Scop.), the weed chosen for this investigation, is widely distributed and difficult to control. It poses a particularly difficult problem in grass seed fields since it does not attain a stage of growth where it is amenable to effective chemical control until the crop is also susceptible to the chemical.

Two grass seed crops were chosen for this study, creeping red fescue (*Festuca rubra* L.) and timothy (*Phleum pratense* L.). Creeping red fescue is the major forage seed crop in Alberta. Timothy is of minor importance as a seed crop in Alberta but ranked as the second largest grass seed crop in Canada during 1969.

Three herbicides which have been effective in varying degrees for the control of Canada thistle were selected. These were 2,4-D (mixed butyl ester of 2,4-dichlorophenoxy acetic acid), dicamba (dimethylamine salt of 3,6-dichloro-o-anisic acid), and picloram (potassium salt of 4-amino-3,5,6-trichloropicolinic acid).

Three approaches were used in order to obtain the best probable weed control with maximum crop tolerance. These included:

1. Control of the weed prior to the seeding of the grass seed crop.

2. Weed control during the establishment year of the grass seed crop.

3. Weed control in established seed production fields.

Herbicide effects on growth of Canada thistle and the two grass species were assessed in different locations and under various experimental conditions. In addition, herbicide residues in soil samples from treated plots were estimated at different times after treatment, and germination percentages of seed produced on treated plots were determined.

# LITERATURE REVIEW

## 1. Grass Seed Production

The success of a grass seed production program is dependent upon several factors including climate, ample moisture, suitable soils, absence of weeds, warm, dry seasons for curing and harvesting the seed, cultural and management practices (6,20,21,26,27,46,48).

Creeping red fescue and timothy are well adapted to the climatic conditions of Northern Alberta. They are cool-season grasses which develop rapidly in the spring, are relatively dormant during periods of high temperatures and drought in summer, and resume active growth in the fall, until freeze-up.

Specific environmental conditions are required by these grasses for flowering and seed production (20,21,57). Three stages can usually be recognized in the flowering cycles of the Gramineae although not all species exhibit all stages of development. The three stages of development have been described as follows (57):

1. Juvenile stage - plants in this stage have not grown and developed sufficiently so that they are sensitive to the environmental conditions which later promote flowering.
2. Inductive stage - plants respond to low temperatures and/ or short photoperiods, and attain a physiological state enabling them to respond to photoperiods which stimulate inflorescence initiation.
3. Stage of realization (initiation) - plants respond to an appropriate photoperiod by producing an inflorescence.

Creeping red fescue must pass through all three stages before a seed head is produced (20). Timothy, on the other hand, may have to pass through a relatively minor juvenile stage, has no inductive requirement but does have a photoperiodic requirement for initiation (57).

Seeding of both grass species is usually carried out with the grass seed attachment of a grain drill. The seeding of grasses in rows as opposed to solid stands has received considerable attention. Solid stands are higher yielding than rows in the first year, but the seed yield rapidly declines in the following years due to a sod-bound condition and depletion of soil moisture and nutrients. Row culture, on the other hand, does not yield as much in the first year as solid stands, but the seed yields are maintained at a higher level for several years (6,21,26,47,48). Although row culture provides an advantage in seed yield, weed problems and soil erosion can occur due to the thinner stand.

Despite any disadvantages, both grasses are seeded in rows spaced 1 foot apart. Creeping red fescue is seeded at a rate of 1 to 2 lb/A and timothy at a rate of 1 lb/A. The rates largely depend on soil moisture conditions and soil type.

Companion crops are sometimes seeded with the grass seed crop. The benefits derived are the companion crop yield and seed suppression (27,48). The disadvantage of such a companion crop is the competition presented to the young grass seedlings. This competition retards the growth and development of the grass crop resulting in reduced stands and seed yields the following year (21,27,48).

2. Weed Control in Forage and Grass Seed Crops

Many of the principles which apply to weed control in pasture and hay crops also apply to grass seed crops. Weeds seriously compete with grasses for moisture, nutrients and light. The result is reduced seed yields and greater losses of seed during the threshing and cleaning processes.

A. Competition Between Canada Thistle and Forage Species

Little information is available on Canada thistle competition with forage grass species but work conducted to date shows that this weed is very competitive. Alfalfa, when periodically mowed, is a good competitor against Canada thistle (65). Thrasher _et al_. (69) demonstrated that Canada thistle was a strong competitor with bluegrass and orchard grass under non-irrigated conditions. They concluded that the lack of competitiveness of these grass species is related to their slow growth in the seedling stages.

Timothy grown in rows for seed presented less competition to thistles. As the timothy row spacing increased there was a corresponding increase in thistle densities (6). Bromegrass grown in rows for seed was less effective in reducing thistle densities than other cropping and treatment combinations even though a 2,4-D treatment and intertillage operation were included each year (40).

Variations were observed in the competitive ability of grass species. The ability of several seedling grasses to withstand weed competition was in the order: bromegrass > crested wheatgrass > orchard grass = red fescue > Kentucky bluegrass (10).

B. Cultural Control of Weeds in Forage and Grass Seed Crops

Probably the most widely used cultural methods of controlling

weeds in forage crops are: cultivation, hand roguing, mowing, burning, and companion crops (17,26,27,40,48,62,65,69).

Companion crops have received considerable attention as a means of cultural weed control, but the disadvantages of any such crops appear to outweigh the advantages (27,48). It is generally agreed that the competition presented by a tall, rapidly growing crop will result in weaker forage plants and delayed productivity (21,27,48).

Genest (27) reports that weed development was poorer under a companion crop as opposed to no companion crop in the year of seeding. The following spring, however, plots on which there was a companion crop were the most heavily infested with weeds. This was attributed to the poor establishment of the forage crop.

Creeping red fescue seeded with a companion crop will require an extra growing season before seed production is realized (20,21). This may be attributed to the failure of the grass to grow and develop to the stage where induction could take place.

Canode and Robocker (10) found intertillage operations effective for weed control and maximum seed production but herbicides produced better results under dry climatic conditions.

C. Tolerance of Grasses to Herbicides

Canode et al. (10,11,12) concluded that the most economical herbicidal control of weeds in seedling grasses is obtained when weeds are eradicated before they have made any appreciable growth.

The sensitivity of grass seedlings to 2,4-D decreases with age, growth and development. Its use is generally delayed until the grasses have three to four leaves and an established root system (10,12, 13,60).

The tolerance of seedling grass species to herbicides varies considerably (2,10,11,12,75). Arnold et al. (2), for example, reported that of four range grass species tested for tolerance to picloram, three were significantly more sensitive than the remaining one.

Dry matter production by timothy was not affected by a number of herbicide combinations (23). Peters et al. (62) found timothy was not visibly injured by picloram at 16 oz/A, 2,4-D at 32 oz/A and 2,4-DB at 32 oz/A.

Seed yields of timothy were significantly reduced when herbicide treatments were applied at the tillering stage of the grass. Greater tolerance was exhibited when treatments were applied at the late boot and heading stage (23). Under British climatic conditions, timothy seed production was adversely affected if treated with 2,4-D and dicamba, 4 to 5 weeks and 6 to 7 weeks prior to heading (4). In the same study, it was observed that dicamba may reduce seed germination percentages if applied at the later dates.

Creeping red fescue seed yields were not reduced by 10 oz/A of 2,4-D if applied up to one week prior to heading or when 25 per cent of the seed was in the hard dough stage (13,21). Other results show that high rates of 2,4-D (16 to 48 oz/A) and picloram (4 to 6 oz/A) applied under lush growing conditions can reduce the seed yield and germination of creeping red fescue (78).

Lee (50) studied the effects of picloram applied in the fall and spring on seed production of creeping red fescue and other grasses. Fall applications were better tolerated by creeping red fescue but rates exceeding 12 oz/A significantly reduced seed yields. All rates of picloram from 4 oz/A up applied in the spring prior to the boot stage

of the crop significantly reduced the seed yield. Associated with reductions in seed yields were visible reductions in the number of seed heads. No treatment resulted in a loss of plants.

3. Canada Thistle Characteristics and Control.

A. General Characteristics

Canada thistle (Cirsium arvense (L.) Scop.), is a widespread and difficult to control perennial weed which reproduces and spreads by means of seeds and horizontal root extension (5,41,52). The troublesome nature of this weed is primarily due to its deep root system.

The underground root system which is extensive and complex is composed of four distinct types of roots (33,61). These include two types of horizontal roots which anatomically are ideal for translocation and storage of food reserves and also serve to propagate and spread the species. Deeply penetrating vertical roots and short fine roots are also present.

Readily available root reserves have been found to fluctuate during the growing season and attain a low level at the flowering stage of the plant (3,77).

Canada thistle is a highly variable plant species (5,24,39, 40). Varieties, strains and ecotypes have been distinguished according to their leaf forms, emergence dates, height, seed weight, flowers, and flowering date.

Bakker (5) studied the environmental requirements for Canada thistle seed germination and seedling growth. Germination requirements of seed are soil temperatures of 30$^{o}$C and well aerated soils with a moisture content of 40 to 50 per cent of field capacity. Thistle

seedlings require full daylight for normal growth and development. These findings help explain the large-scale establishment of thistles from seed on bare or thinly vegetated soils on roadside fill sections (22).

Supplemental nitrogen can cause increases in Canada thistle stands (6,40). Under irrigated conditions, thistle stands decreased in grass crops when fertilized at rates of 200 to 400 lb/A of nitrogen (65). Rates of 100 lb/A or less of supplemental nitrogen resulted in increased thistle stands under the same conditions.

B. Cultural Control Methods

Mowing, cultivation, and competitive crops or a combination of these are effective for the control or eradication of Canada thistle (3,17,29,40,41,52,55,63,65,69,77). Mowing when root reserves are at a minimum is usually effective but must be repeated over a period of at least four years (3,41,77).

Substantial reductions in thistle stands can be achieved in one season if cultivations are repeated every 21 to 28 days or when thistles have reached a height of approximately 4 inches (17,40,41,52, 54,55).

Competitive crops can be used effectively to reduce or eliminate thistle stands (17,40,41,52,63,65,69). Fall rye, hay crops alfalfa, grass crops, and cereals in combination with various management practices are all effective.

C. Chemical Control Methods

The herbicides 2,4-D, dicamba and picloram are effective in different degrees for the control of Canada thistle in Alberta.

The use of 2,4-D is widely recommended (13,17,40,52,55,64).

Applications of 9 to 12 oz/A at the bud stage of thistles provide top growth control but do not usually stop regrowth from roots. Three or more years of treatment with 2,4-D are necessary in order to effect appreciable stand reductions.

Dicamba at rates of 16 to 32 oz/A has proven more effective for thistle control than 2,4-D (29,35,42,43,44,45,55,59), though occasionally its superiority to 2,4-D has been open to question (24,72).

Considerable attention has been directed towards picloram for the control and eradication of Canada thistle and other deep-rooted perennial weeds. Research to date has shown it to be the most effective herbicide of the three discussed here for thistle control (1,22,24,29, 35,42,43,44,45,53,55,73,74,75). Rates of 4 to 12 oz/A provide good control of thistle regrowth for up to 3 years. Gupta (29) reported that one ounce of picloram per acre applied where foxtail barley provided competition, resulted in more than 90 per cent control of dense Canada thistle and perennial sow thistle regrowth one year after treatment.

Picloram's effectiveness is attributed to its ability to cause severe damage to the root system of Canada thistle (16,49,51). Studies with picloram show that foliar treatment results in swelling, splitting and deterioration of the root system of treated plants. Dicamba or 2,4-D caused only slight damage to cellular structures in the below-ground portions of the plant.

4. Soil Residues of Herbicides

A. Herbicide Residues and Crop Production

Phytotoxic herbicide residues remaining in the soil for an extended period of time are a concern if subsequent crops in a rotation program have low tolerance to the herbicide. This residual behavior is

usually due to either slow decomposition of the herbicide or inadequate quantities of incident moisture which would leach the herbicide from the upper soil horizons. Both of these factors contribute to the relatively slow dissipation of herbicides in most Alberta soils.

The use of 2,4-D at recommended rates does not pose any herbicide residue problem to subsequently grown crops (41,52).

Dicamba is known to be persistent at rates exceeding 16 oz/A (1,18,25,30,43,44,55,59,67). Phytotoxic residues may remain in the soil for as long as two years. It is recommended that small grains instead of broadleafed crops be seeded the year following treatment at a rate which exceeds 16 oz/A.

Picloram is a highly persistent herbicide (1,14,24,31,32,36, 37,45,55,71,76). Rates of 8 to 48 oz/A will not permit establishment of such crops as alfalfa, sweet clover, field beans, sunflower, or soybeans for at least three years. Rates as low as 4 to 6 oz/A cause noticeable shortening and epinasty of wheat grown the year following treatment (14). Corn and oats, on the other hand, are quite tolerant to picloram residues (1).

B. Factors Influencing the Dissipation of Herbicides in Soil

Dicamba is a mobile compound (9,18,25,34). Its mobility is limited mainly by the organic matter content of a soil and the amount of rainfall (18,70). The leaching of a herbicide is not an important means of dissipation in Alberta soils due to relatively low rainfall conditions.

Dicamba persists in the soil for a longer period than 2,4-D (25,67). Factors directly or indirectly influencing the persistence of the herbicide under laboratory conditions include soil pH (15), soil

organic matter content (18), soil temperature (9,30), soil moisture content (9), the soil horizon at which the herbicide is concentrated (30), and the microbial activity in the soil (9,15,18,25,30,67).

Extensive studies have been conducted on the persistence of picloram. The dissipation of this herbicide under field conditions is influenced by leaching (37,46,56,58,66), rate of application (31,32,37, 46), soil temperature (32,66), plant cover (58), and soil organic matter content (37,66). Hamaker _et al._ (32) report that the rate of loss of picloram was most highly correlated with days over 90$^{0}$F, annual precipitation and rate of application.

Laboratory studies have provided more qualitative and quantitative information about the factors influencing picloram decomposition (15,31,54,56,79).

# MATERIALS AND METHODS

Experiments were conducted in the field, in a greenhouse, and in a growth chamber during 1969 and 1970 to assess the tolerance of grasses to three herbicides. The herbicide formulations used throughout this study included the mixed butyl ester of 2,4-D, the dimethylamine salt of dicamba, and the potassium salt of picloram. Timothy (*Phleum pratense* L.) and creeping red fescue (*Festuca rubra* L.) were the grass species tested.

## 1. Field Experiments.

### A. General

Experimental plots were located at Peoria, St. Albert, Legal, Warspite, Spedden, Ellerslie, and Bezanson. All plots were arranged in randomized complete block designs with the exception of those at Legal and Ellerslie which were split-plots. Unless stated otherwise, treated plots were 10 by 30 feet in size. Plots in thistle-infested areas were separated by an untreated strip 2 feet wide. Treatments were replicated three times, except at one location (Bezanson) where they were replicated four times.

Rates of herbicides used at all locations except Legal were 16 oz/A of 2,4-D; 8, 16 and 24 oz/A of dicamba; 2, 4, 8 and 12 oz/A of picloram. At Legal the 24 oz/A rate of dicamba was replaced by 32 oz/A, and the 2 oz/A rate of picloram by 16 oz/A. Herbicides were applied with a plot sprayer in 5 gallons of water per acre at 38 psi pressure.

All Canada thistle shoot counts and seed harvests were carried out using three or four one-yard square quadrats per plot. Canada thistle survival was calculated as the ratio of the number of thistle

shoots per square yard emerging one year after treatment (follow-up count) over the number of thistle shoots per square yard at the time of treatment (initial count). For the statistical analysis, all ratios were expressed as a percentage of the largest ratio in the experiment. The arc sine transformation was applied to the percentage data for the statistical analysis.

Grass clippings were dried to constant weight at 105$^{o}$C for dry matter yield determinations.

Samples from plots at Peoria, Spedden, and Bezanson were harvested, bagged, and placed on a drying rack for at least one month. The contents were then threshed and the grass seed was cleaned to a high degree of purity.

B. Tolerance of Grasses to Preplant Soil-Applied Herbicides

Trials at Legal and Ellerslie were primarily designed to test the tolerance of the two grass species to soil herbicide residues. The herbicides were applied 9 months (Legal) or 22 days (Ellerslie) prior to seeding (Table 2). Plots measured 10 by 20 feet in both experiments.

i) Legal

The site was uniformly infested with Canada thistle, and thistles were in the bud stage when treated. Initial thistle shoot counts and follow-up counts were made on four individual square yard quadrats in each plot.

The plot area was rotovated to a depth of four inches and packed with a drum-type packer prior to seeding. Each herbicide-treated main-plot was divided into two sub-plots which then were seeded to timothy and creeping red fescue. The grasses were seeded with a V-belt seeder, in three rows spaced 1 foot apart, at a rate of 25 seeds per foot of row. Grass plant counts were made in the center 10 feet

of the two rows nearest the center of the main-plots.

ii) Ellerslie:

The site was cultivated and harrowed prior to the application of herbicides. Three weeks following herbicide application the plots were rotovated and seeded as at Legal. Plots were handweeded periodically to maintain a near-weedfree condition.

Grass plants were counted and top-growth was clipped at soil level on the center 10 feet of the three rows in each sub-plot.

C. Tolerance of Creeping Red Fescue Seedlings to Herbicides

Two experiments, at Warspite and at St. Albert, were conducted to assess the effects of herbicides on seedling grass plants and Canada thistle (for dates of operations see Table 2).

i) St. Albert

Prior to seeding, the plot area was cultivated and harrowed. Seeding was done with the grass seed attachment of a double disc press drill. Creeping red fescue (cv. Boreal) was seeded at a rate of 0.5 lb/A in rows spaced 1 foot apart.

Grass plants were counted and top-growth was clipped at soil level in the center eight feet of one row in each plot.

ii) Warspite

Creeping red fescue (cv. Dawson) was seeded with the grass seed attachment of a double disc press drill in rows spaced 1 foot apart, at a rate of 2 lb/A.

Grass plants were counted and top-growth was clipped at soil level in the center 10 feet of one row in each plot.

Table 2 Summary of dates when operations were performed and crop stage when treated at various plot locations.

| Location | Seeding Date | Spray Date | Growth stage at Spray time: Grass | Growth stage at Spray time: Thistles | Dates of grass count & harvest | Dates of thistle shoot counts |
|---|---|---|---|---|---|---|
| Legal | 6-6-70 | 22-8-69 | preseeding | bud | 4-10-70 | 22-8-69<br>14-7-70 |
| Ellerslie | 3-6-70 | 12-5-70 | preseeding | - | 27-9-70 | - |
| St. Albert | 3-7-69 | 19-8-69 | 1-4 tillers per plant | bud | 26-9-70 | 19-8-69<br>27-6-70 |
| Warspite | 2-8-69 | 28-9-69 | 3-5 tillers per plant | early bud | 16-10-70 | 28-9-69<br>15-7-70 |
| Peoria | 1965[a] | 21-6-69 | 10% anthesis | early bud | 29-7-69<br>22-7-70 | 3-7-69<br>13-7-70 |
| Spedden | 1968[a] | 28-9-69 | post-harvest | - | 26-8-70 | - |
| Bezanson | 1968[a] | 21-5-70 | 3-4 leaves/ tiller | - | 20-8-70 | - |
| | | 1-6-70 | 5-7 leaves/ tiller | - | - | - |
| | | 21-7-70 | 2 wks post-flowering | - | - | - |

[a] Only the year of seeding was available.

D. Tolerance of Established Grass Seed Production Stands to Herbicides

Experiments were conducted on seed production fields at Peoria, Spedden, and Bezanson to assess the effects of herbicides on the yield and quality of grass seed (for spraying and harvesting dates see Table 2).

i) Peoria

The site was infested with Canada thistle. This provided an opportunity to assess the effects of a single herbicide application on thistle stand densities.

The creeping red fescue (cv. Boreal) was seeded with a companion crop in 1965 and was relatively dense by 1969. In 1966 the grass crop produced no seed and was clipped several times to reduce weed seed production. The crop was sprayed with 12 oz/A of 2,4-D in 1966 and again in 1967. There was no apparent effect on the Canada thistle stand from these treatments.

Seed yields were estimated by sampling four individual square yards on each plot.

ii) Spedden

This trial was conducted on a field of timothy (cv. Evergreen) from which the first seed crop had been harvested. The timothy stand was uniform and only a few weeds were present.

Seed yields were estimated by sampling four individual square yards of each plot.

iii) Bezanson

The plot area, in a field of timothy (cv. Evergreen) was practically weedfree except for a light infestation of dandelions

(Taraxacum officinale Weber). Herbicides were applied at three different growth stages (Table 2).

Three individual square yards in each plot were sampled for seed yield estimates. Plots measured 5 by 25 feet.

E. Effect of Herbicides on Tiller and Grass Seed Production Under Growth Chamber Conditions.

This study was undertaken to more fully determine the effect of picloram and dicamba on the tillering and seed production of creeping red fescue.

Uniform plants of creeping red fescue (cv. Dawson) were collected from various plots in the Warspite experiment on October 4, 1970, potted in 6-inch diameter plastic pots the following day, and placed in a growth chamber. Two plants were taken from each replicated treatment making a total of six replications for each treatment in the growth chamber study. Plots from which plant samples were obtained included the untreated check, dicamba at 16 oz/A, and picloram at 4 and 12 oz/A.

The growth chamber was set to provide light for 8 hours and darkness for 16 hours. The light intensity was approximately 19,400 lux at plant level. Temperatures were set for 7$^{o}$C with lights on and 5$^{o}$C with lights off and these settings were maintained for 20 weeks. At the end of this period the daylength was set at 14 hours, with the temperatures remaining the same. Three weeks later, on March 19, 1971, the temperature was increased to 21$^{o}$C and the daylength to 20 hours. On May 8, 1971, fertile tillers were counted and seed yields were determined. The grass was clipped to soil level and ten cucumber seeds were planted in each pot. The pots were then placed in the growth chamber (21$^{o}$C,

20-hour daylength). Injury symptoms on the cucumber seedlings provided an indication of herbicide residues remaining in each pot after three weeks in the growth chamber (cf. section on 'Bioassay of herbicide residues', page 23).

F. Germination Trials

All grass seed samples from plots at Peoria, Spedden, and Bezanson were tested for germination according to routine procedures[1].

Covered 9 cm crystallization dishes with a single layer of Whatman No. 1 filter paper in the bottom of each dish served as the germination unit. Dishes with filter paper and lids were sterilized in an autoclave and after cooling, 2.5 ml of distilled water was added to each dish. Equal quantities of seed from plots in the three or four replicates were mixed thoroughly to make a composite seed sample for each herbicide treatment at each location. One hundred seeds from each composite seed sample were placed in a germination unit. Four replicates were used for timothy seed samples, and two for the fescue seed samples, in accordance with recommendations in the seed testing manual[1].

Seed of both species was subjected to alternating light and temperature conditions in a growth chamber as recommended in the seed testing manual. Creeping red fescue seedlings were counted 7, 14, and 21 days, and timothy seedlings 7 and 10 days following introduction into the growth chamber. Only seedlings which appeared "normal" were considered as germinated. Tests were terminated after the final seedling

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[1] Methods and procedures of seed testing. 1965. Pub. by Plant Products Division, Production and Marketing Branch, Canada Department of Agriculture.

count. The experimental designs were completely randomized experiments.

2. Greenhouse Experiments

Two greenhouse studies were undertaken during 1970 to assess the tolerance of creeping red fescue (cv. Dawson) and timothy (cv. Evergreen) to soil-applied and foliar-applied herbicides.

A. General

Air temperature in the greenhouse was maintained at approximately 20$^{\circ}$C but between May 1, 1970 and October 1, 1970, it occasionally rose to 35$^{\circ}$C. Supplementary light was provided during the winter months to ensure a daylength of 16 hours.

Soil mistures consisted of 50 per cent by weight of sand and 50 per cent of Malmo silty loam. The soil mixtures were initially fertilized with 50 ppmw (oven-dry basis) of nitrogen

For moisture holding capacity determinations, four pots filled with equal weights of the soil mixture were left overnight in one inch of water. The pots were then removed and drained for three hours. After the grass seed was planted, soil in the pots was brought to 90 per cent of moisture holding capacity. Brown wrapping paper was placed over the pots until seedlings emerged.

Herbicides were applied with a cabinet sprayer in 10.2 gallons of water per acre at 37 psi pressure. Table 3 presents other details of herbicide applications and operations.

In both instances the experimental layout was a completely randomized factorial design.

B. Tolerance of Grasses to Soil-Applied Herbicides

The effects of soil-applied herbicides on grass survival and dry matter production were assessed in this experiment.

Table 3 Details of herbicide applications in greenhouse experiments.

| Experiment | Herbicides used | Herbicide dosage (oz/A) | Spray Date | Growth stage of grass | Harvest date |
|---|---|---|---|---|---|
| Soil applied treatments | 2,4-D | 16 | 13-1-70 | preplant treatment | 9-5-70 |
| | dicamba | 8,16,24 | | | |
| | picloram | 2,4,8,12 | | | |
| Foliar applied treatments | 2,4-D | 16 | 8-6-70 | 3-4 leaves per plant | 24-9-70 |
| | dicamba | 8,16 | 22-6-70 | 1-3 tillers per plant | |
| | picloram | 4,8 | 6-7-70 | 3-6 tillers per plant | |

Plastic pots, 7 inches in diameter were filled with 2.9 kg of the soil mixture. Herbicide solutions were applied to the surface of the potted soil. Enough water was added to each pot to bring the moisture content to 90 per cent of moisture holding capacity of the soil.

After one week, the soil in half of the pots was worked thoroughly to a depth of 2.5 to 3.0 inches. Fifty grass seeds were planted in each pot and lightly worked into the soil surface. Four weeks following emergence and when grass seedlings were in the 3- to 4- leaf stage, the surviving plants were counted. All pots were then thinned to two plants per pot and watered daily to maintain moist soil conditions. Eighty-one days after thinning, grass plants were clipped at soil level for dry matter yield determinations.

C. Tolerance of Grasses to Foliar-Applied Herbicides

Herbicides were applied to the two grass species at three different growth stages, and the effects on survival and dry matter production were assessed.

Three grass plants were established in 6-inch diameter plastic pots. As the grass plants grew, the herbicide solutions were applied at the appropriate growth stage. Seven weeks following the first herbicide application the number of surviving plants was recorded. Eight weeks later the grass plants were clipped at soil level for dry matter yield determinations.

3. Bioassays of Herbicide Residues in Soil

Soil residues of dicamba and picloram were estimated by the method of Dowler (19). Cucumbers (*Cucumis sativus* L. cv. Early Russian) served as the bioassay plants. Soil samples from all plot locations except Bezanson were included in the bioassay.

Two soil cores, to a 6-inch depth, were taken from each treated plot and mixed to form a composite sample for each treatment at each plot location. Samples were air-dried in a greenhouse at approximately 20$^{o}$C for 2 to 3 weeks. Dried soil samples were crushed, run through a 2 mm sieve and thoroughly mixed.

A standard concentration series of 0, .001, .003, .009, .027, .081, .243, and .729 ppmw (oven-dry basis) picloram and dicamba was made up with soil samples from untreated plots. Equal amounts of soil were placed in 3-inch diameter plastic pots. Each pot was seeded with four cucumber seeds, brought to 90 per cent of the predetermined moisture holding capacity and covered with brown wrapping paper until seedlings emerged. When cucumber plants had one full-grown true leaf, the plants in soil from treated plots were compared to plants in the standard concentration series and the residual soil herbicide concentrations were estimated on the basis of plant symptoms (Figures 6 and 7). Comparisons were repeated when plants in the untreated soil had three true leaves. Greenhouse air temperature was about 23$^{o}$C and supplementary lighting provided a daylength of 14 hours.

A soil texture analysis and soil organic matter determination were conducted on soil samples from untreated plots at each of the locations. Duplicate determinations were performed in each instance. The soil texture analysis was done according to the method of Bouyocous (8) on an organic-matter-free basis. The soil organic matter determinations were conducted in accordance with the Walkley-Black method (7).

# RESULTS AND DISCUSSION

## 1. Field Experiments

### A. Chemical Control of Canada Thistle

A sufficiently dense and uniform stand of Canada thistle was present at the Legal, St. Albert, Peoria, and Warspite plots so that shoot counts could be made to determine herbicide effectiveness.

Canada thistle densities on untreated plots had increased at all locations one year after the initial stand count (Table 4). Treatments with 2,4-D were ineffective for thistle control except at Legal where they significantly reduced the thistle shoot count relative to untreated plots. All 2,4-D treatments caused a delay in budding and flowering of the thistles.

Dicamba at 8 and 16 oz/A gave inconsistent results. On plots treated with 8 oz/A at St. Albert the thistle stand density increased significantly. At Peoria the 16 oz/A treatment resulted in a greater reduction in thistle shoots than did the 24 oz/A treatment. Only the 32 oz/A application of dicamba at Legal produced excellent thistle control,as good as that provided by the picloram treatments. Dicamba delayed the budding and flowering of thistles and this effect was intermediate between that of 2,4-D and picloram.

The inconsistent response to dicamba at 16 oz/A probably can be attributed to a lack of uniformity in the thistle infestation and the fescue stand, with a light thistle infestation and a dense fescue stand on the plots that received this treatment. Seed yield data reported later (Table 8) support this explanation.

Picloram at rates of 8, 12, and 16 oz/A was consistently

Table 4 Canada thistle shoots emerging one year following a single herbicide treatment, expressed as a percentage* of the initial stand.

| Treatment | Location<br>Legal | St. Albert | Peoria | Warspite |
|---|---|---|---|---|
| Check | 310 a | 214 b | 165 ab | 284 a |
| 2,4-D, 16 oz/A | 186 b | 175 b | 234 a | 273 a |
| Picloram, 2 oz/A | - | 218 b | 49 bc | 251 ab |
| Picloram, 4 oz/A | 34 cde | 142 bc | 43 c | 111 d |
| Picloram, 8 oz/A | 9 de | 65 c | 38 c | 29 e |
| Picloram, 12 oz/A | 7 e | 52 c | 0 c | 27 e |
| Picloram, 16 oz/A | 1 e | - | - | - |
| Dicamba, 8 oz/A | 166 bc | 277 a | 168 ab | 225 abc |
| Dicamba, 16 oz/A | 124 bcd | 204 b | 49 bc | 167 bcd |
| Dicamba, 24 oz/A | - | 120 bc | 158 ab | 135 cd |
| Dicamba, 32 oz/A | 17 de | - | - | - |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test.

* Percentage thistle emergence one year following treatment = shoots emerged one year following treatment divided by the initial stand density, multiplied by 100. Data are means of three replicates.

superior to all other herbicide treatments in reducing thistle stands, but there was never a significant difference between the effects of these rates of this herbicide. Severe delays in budding and flowering of thistles resulted from picloram in the year following treatment. Surviving thistle plants were stunted, twisted, and swollen at the shoot apex. These results agree with those obtained by others (1,22, 24,29,35,42,43,44,45,53,55,71,73,74,75). The order of effectiveness of the herbicides agrees with the findings of Gupta (29).

Other factors influencing the effectiveness of the herbicides were apparent. Thistle control with herbicides at St. Albert was not as good as at other locations. This was attributed to a strain or ecotype of Canada thistle which was resistant to the herbicides. Hodgson's study (38) showed that certain ecotypes of Canada thistle exhibited definite differences in susceptibility to herbicides.

The control of Canada thistle at Legal was better than that obtained in other plots. The plot was rotovated prior to seeding and this cultivation probably resulted in the superior control. This agrees with the findings of others that cultivation in addition to chemical treatments is effective for reducing thistle stands (1,17,38,40,73,74).

Herbicide treatments at Warspite were applied in early October following a cool, wet period. Thistle stand reductions were not as great as in plots at other locations, probably because of the late treatment time.

The competition presented to the thistles by the grass stand at Peoria enhanced the killing effect of the herbicides. This was the only plot on which a herbicide treatment effected 100 per cent thistle eradication; this was obtained with picloram at 12 oz/A.

B. Tolerance of Grasses to Preplant Herbicide Applications

Herbicide residues remaining in the soil in the Legal plots resulted in a trend towards lower plant numbers with increasing rates of picloram and dicamba (Table 5). These reductions in plant stands were not significant, however, individual grass species means did not reflect this trend as definitely.

Dicamba treatments of 16 and 24 oz/A at Ellerslie significantly reduced grass plant numbers (Table 5). Grass dry matter production was significantly reduced by all rates of dicamba and 12 oz/A of picloram. Creeping red fescue displayed a greater ability to become established than did timothy (Table 6). This is supported by the yield data in Table 6 which indicate that dicamba at 24 oz/A completely inhibited the establishment of timothy but not that of creeping red fescue.

Timothy dry matter production was significantly higher than that of creeping red fescue at Ellerslie. This can be explained by the fact that timothy plants grow more rapidly and produce larger plants than fescue (Figure 1).

Figure 1 (lower) shows the inhibitory effect of a soil treatment with dicamba at 8 oz/A on the growth of timothy and creeping red fescue. The upper photograph shows "normal" growth and development of the two grasses.

During 1970, thistle stands at Legal on untreated plots and plots treated with 2,4-D at 16 oz/A or dicamba at 8 and 16 oz/A were sufficient to result in grass plants that were spindly and poorly developed. Grass plants on the remaining plots were larger and better developed. By the end of the 1970 growing season no epinastic effects

Table 5 Tolerance of grass species to soil-applied herbicides at Legal and Ellerslie.

| | Location | | |
|---|---|---|---|
| | Legal | Ellerslie | |
| Treatment | Plant count | Plant count | Dry matter (gm) |
| Check | 12.5* a | 29.2** a | 407.8** a |
| 2,4-D, 16 oz/A | 21.2 a | 25.0 a | 323.9 ab |
| Picloram, 2 oz/A | - | 25.8 a | 380.2 ab |
| Picloram, 4 oz/A | 17.2 a | 28.3 a | 450.3 a |
| Picloram, 8 oz/A | 14.2 a | 23.2 ab | 340.1 ab |
| Picloram, 12 oz/A | 12.0 a | 19.5 ab | 226.4 cd |
| Picloram, 16 oz/A | 11.3 a | - | - |
| Dicamba, 8 oz/A | 17.3 a | 18.5 ab | 236.0 bc |
| Dicamba, 16 oz/A | 15.5 a | 14.3 b | 178.8 d |
| Dicamba, 24 oz/A | - | 1.2 c | 5.8 e |
| Dicamba, 32 oz/A | 13.5 a | - | - |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test.

Data for the two grass species are combined.

* Number of plants in center 10 feet of two rows, mean of six sub-plots.

** Plant number and dry weight in center 10 feet of three rows, mean of six sub-plots.

Table 6 Dry matter production by timothy and creeping red fescue at Ellerslie on plots treated with herbicides before planting.

| Treatment | Dry weight, gm per 10 ft row<br>Timothy | <br>Creeping red fescue |
|---|---|---|
| Check | 686.6* | 128.9* |
| 2,4-D, 16 oz/A | 512.0 | 135.9 |
| Picloram, 2 oz/A | 643.3 | 117.1 |
| Picloram, 4 oz/A | 730.8 | 169.8 |
| Picloram, 8 oz/A | 525.5 | 127.8 |
| Picloram, 12 oz/A | 362.1 | 90.7 |
| Dicamba, 8 oz/A | 373.9 | 98.0 |
| Dicamba, 16 oz/A | 307.6 | 50.1 |
| Dicamba, 24 oz/A | 0.0 | 11.5 |

* Means of three replicates.

Figure 1. Comparison of the effects of preplant herbicide treatments on grass crops at Ellerslie. Small, dark green plants are creeping red fescue and large, light green plants are timothy. Upper: untreated check. Lower: dicamba at 8 oz/A. Plots were seeded June 3, 1970, and photographed on October 2, 1970.

due to soil herbicide residues were observed on the grasses at Legal and Ellerslie.

The results of this study agree with those of other researchers (2,12).

C. Tolerance of Creeping Red Fescue to Foliar-Applied Herbicides

Herbicide treatments caused no significant reductions in fescue plant counts or dry matter production at either St. Albert or Warspite when grass plants were treated at the 1 to 4 or the 3 to 5 tillers per plant stages of growth (Table 7). There was a trend towards lower plant counts with increasing rates of picloram and particularly dicamba at Warspite, but differences were not statistically significant.

Picloram at 4, 8, and 12 oz/A and dicamba at 16 and 24 oz/A caused prostation symptoms on fescue plants. These symptoms were most noticeable at the highest rate of each herbicide.

In plots where thistle growth was not controlled to any appreciable extent, creeping red fescue plants were reduced in growth and development. This was apparent in untreated plots and in plots treated with 2,4-D at 16 oz/A, dicamba at 8 and 16 oz/A and picloram at 2 oz/A.

During 1969 and 1970, wild oats (*Avena fatua* L.) in the plots at St. Albert partially masked the beneficial effects derived from thistle control. This also occurred at Warspite but not to as great an extent.

The results of these field experiments concur with the findings of others in that once grasses have an established root system and 3 to 4 leaves per plant they are tolerant to many herbicides (10,12, 13,60).

Table 7 Effects of foliar-applied herbicides on plant numbers and dry matter production of creeping red fescue at St. Albert and Warspite.

| | Location | | | |
|---|---|---|---|---|
| | St. Albert[a] | | Warspite[b] | |
| Treatment | Dry matter (gm) | Plant count | Dry matter (gm) | Plant count |
| Check | 98.8* | 9.7* | 81.9* | 20.3* |
| 2,4-D, 16 oz/A | 94.4 | 3.7 | 76.6 | 20.7 |
| Picloram, 2 oz/A | 74.1 | 6.0 | 113.6 | 19.3 |
| Picloram, 4 oz/A | 52.7 | 6.3 | 114.2 | 19.7 |
| Picloram, 8 oz/A | 52.2 | 6.0 | 98.5 | 18.0 |
| Picloram, 12 oz/A | 131.1 | 6.0 | 116.7 | 17.7 |
| Dicamba, 8 oz/A | 30.9 | 5.3 | 70.5 | 21.0 |
| Dicamba, 16 oz/A | 68.8 | 7.0 | 86.1 | 17.3 |
| Dicamba, 24 oz/A | 81.1 | 6.0 | 68.1 | 16.0 |

* Means of three replicates. Differences between means were not significant.

[a] Dry weights and plant numbers in an eight foot row.

[b] Dry weights and plant numbers in a ten foot row.

D. Tolerance of Established Grass Seed Production Stands to Herbicides

i) Peoria

There was a significant reduction in creeping red fescue (cv. Boreal) seed production on plots treated in 1969 with 2,4-D at 16 oz/A, picloram at 12 oz/A and dicamba at 8 and 24 oz/A (Table 8). One week following herbicide applications all picloram and dicamba treatments caused bending of the seed tillers. Dicamba at 24 oz/A and picloram at 12 oz/A were most severe and about equal in this respect.

Seed yields in 1970 were not significantly reduced by any of the 1969 herbicide treatments. Picloram at 8 and 12 oz/A, however, caused visible bending of seed tillers, a delay in maturity, and a reduction in the number of seed heads. Figure 2 (lower) illustrates the effects of the 12 oz/A picloram treatment.

In 1969, the year when treatments were applied, dicamba at 16 oz/A did not significantly reduce the seed yield but the 8 and 24 oz/A rates did reduce it. This anomaly was attributed to the greater density of the fescue stand in the 16 oz/A dicamba plots. With due consideration of this fact, all rates of dicamba used in this study would be expected to significantly reduce fescue seed yields when applied at anthesis.

Lee (50) reported that picloram applied in the spring prior to the boot stage of creeping red fescue, at rates of 4 oz/A and higher, significantly reduced seed yields. Lee's results do not agree with those of this investigation as rates up to 8 oz/A were safe at the flowering stage of the crop. This difference in results could be due

Table 8 Effect of herbicides applied in 1969 at Peoria on seed yields of creeping red fescue in 1969 and 1970.

| Treatment | Seed yield, gm/sq yd 1969 | 1970 |
|---|---|---|
| Check | 20.0 ab | 14.6 a |
| 2,4-D, 16 oz/A | 13.9 bcd | 11.5 a |
| Picloram, 2 oz/A | 21.6 a | 21.5 a |
| Picloram, 4 oz/A | 18.4 abc | 15.0 a |
| Picloram, 8 oz/A | 17.0 abcd | 14.2 a |
| Picloram, 12 oz/A | 13.2 cd | 13.4 a |
| Dicamba, 8 oz/A | 14.4 bcd | 16.1 a |
| Dicamba, 16 oz/A | 15.8 abcd | 15.7 a |
| Dicamba, 24 oz/A | 10.4 d | 14.1 a |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test. Data are means of three replicates.

Figure 2. Comparison of the effects of herbicide treatments applied in 1969 on creeping red fescue. Photographed in 1970. Upper: untreated check. Lower: picloram at 12 oz/A.

to several factors including differences in climatic conditions between Alberta and Oregon, the stage of the crop when the herbicides were applied, and varietal responses. The effects of the 8 and 12 oz/A picloram treatments on the fescue in 1970 (Figure 2) agree with those observed by Lee (50).

ii) Spedden

Fall applications of dicamba at 16 and 24 oz/A significantly reduced timothy seed yields the following year (Table 9). Dicamba at 24 oz/A also significantly reduced the height of timothy. Although other treatments resulted in no significant reductions, visual observations and the data suggested that a number of them did affect the seed yield and height of the crop. Dicamba at 8 oz/A and 2,4-D at 16 oz/A evidently reduced the seed yield. Visible height reductions occurred in plots treated with 8 and 16 oz/A of dicamba.

iii) Bezanson

With the exception of the 12 oz/A picloram treatment applied two weeks following the peak flowering period, none of the picloram treatments, regardless of the growth stage when applied, had a significant effect on the seed yield of timothy (Table 10). All dicamba treatments and the earlier 2,4-D treatments significantly reduced the seed yields.

Dicamba applied at the two earliest growth stages caused height reductions, stem bending, delayed maturity, and a reduction in the number of seed heads. The two earlier applications of picloram at 8 and 12 oz/A caused some stem bending and delayed maturity but this was much less severe than that caused by dicamba at 8 oz/A. When 2,4-D was applied at the two earlier growth stages, there were slight reductions in seed head numbers and height.

Table 9 Effects of herbicides applied in 1969 at Spedden on the 1970 seed yield and height of timothy.

| Treatment | Seed yield, gm | Height, cm |
|---|---|---|
| Check | 110.3 a | 63.5 a |
| 2,4-D, 16 oz/A | 93.7 a | 61.7 a |
| Picloram, 2 oz/A | 110.9 a | 62.5 a |
| Picloram, 4 oz/A | 102.1 a | 60.7 a |
| Picloram, 8 oz/A | 109.8 a | 60.8 a |
| Picloram, 12 oz/A | 106.3 a | 61.0 a |
| Dicamba, 8 oz/A | 94.4 a | 59.0 a |
| Dicamba, 16 oz/A | 47.4 b | 58.2 ab |
| Dicamba, 24 oz/A | 38.5 b | 53.5 b |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test. All data are means of three replicates.

Table 10 Effect of herbicides on timothy seed production at Bezanson when applied at different growth stages.

| Treatment | Seed yield, gm/3 sq yd Stage 1 | Stage 2 | Stage 3 |
|---|---|---|---|
| Check | 43.8 abc | | |
| 2,4-D, 16 oz/A | 19.5 de | 31.5 cd | 41.1 abc |
| Picloram, 2 oz/A | 47.1 abc | 50.4 ab | 51.7 a |
| Picloram, 4 oz/A | 40.9 abc | 45.8 abc | 44.5 abc |
| Picloram, 8 oz/A | 42.0 abc | 46.4 abc | 41.7 abc |
| Picloram, 12 oz/A | 45.1 abc | 44.6 abc | 33.5 bcd |
| Dicamba, 8 oz/A | 8.3 ef | 2.6 f | 29.7 cd |
| Dicamba, 16 oz/A | 3.5 f | 1.6 f | 32.6 cd |
| Dicamba, 24 oz/A | 1.7 f | 1.8 f | 33.1 bcd |

Means followed by the same letter are not significantly different from each other as determined by Duncan's new multiple range test. Data are means of four replicates.

Growth stages at treatment time were;

Stage 1: 3 to 4 leaves per tiller, May 20, 1970

Stage 2: 5 to 7 leaves per tiller, June 1, 1970

Stage 3: Two weeks following peak flowering period, July 21, 1970

Herbicides were best tolerated at the latest growth stage. There was no apparent difference between herbicide applications at the two earliest growth stages.

Information is not available regarding the use of picloram on this seed crop. The results obtained from this investigation with dicamba and 2,4-D are supported by the findings of others (4), although Forsberg et al. (23) found timothy to be more tolerant to herbicides at the late boot and heading stage than at the tillering stage, a difference not observed in this study.

E. Effect of Herbicides on the Fertile Tiller and Seed Production of Creeping Red Fescue Under Growth Chamber Conditions.

Picloram at 12 oz/A applied in the field, caused a significant increase in the number of fertile tillers of grass plants transferred from the field plots to a growth chamber (Table 11). No significant differences occurred between seed yields of plants given the various treatments.

All plants from the treated plots appeared to grow and develop normally (Figure 3). Figure 4 illustrates that phytotoxic residues were still present in the soil from 4 and 12 oz/A picloram-treated plots as indicated by the injury symptoms on the cucumber plants. Grass regrowth after clipping was not inhibited by these residues (Figure 4).

Thistle control in the field was sufficiently important in this experiment, that the larger and better developed plants obtained from the field produced a greater number of fertile tillers. Both the 4 and 12 oz/A picloram treatments gave superior thistle control and plants from these plots subsequently produced more tillers than did

Table 11 Effect of herbicides on fertile tiller production and seed production of creeping red fescue cv. Dawson grown under growth chamber conditions.

| Treatment | Fertile tillers per pot | Seed yields grams per pot |
|---|---|---|
| Check | 94.8 a | 3.4 a |
| Dicamba, 16 oz/A | 95.0 a | 3.8 a |
| Picloram, 4 oz/A | 124.8 ab | 2.8 a |
| Picloram, 12 oz/A | 154.2 b | 3.9 a |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test.

Figure 3. Dawson creeping red fescue after floral induction and initiation in a growth chamber. From left to right: untreated check, dicamba at 16 oz/A, picloram at 4 oz/A and picloram at 12 oz/A. Herbicide treatments were applied to field plots from which plants later were collected for transfer to the growth chamber.

Figure 4. Cucumber bioassay of pots for soil herbicide residues following floral induction and initiation in a growth chamber. From left to right: untreated check, dicamba at 16 oz/A, picloram at 4 oz/A, and picloram at 12 oz/A. Herbicide treatments were applied to field plots from which plants later were collected for transfer to the growth chambers.

plants from untreated or dicamba-treated plots. These observations serve to exemplify the importance of thistle control in grasses grown for seed production.

No significant differences between seed yields were detected although the results from the 4 oz/A picloram treatment were lower (Table 11). This lack of significant differences may be attributable in part to the response of the grass under these particular growth chamber conditions.

F. Germination Tests

The germination of creeping red fescue seed harvested at Peoria in 1969 was significantly reduced by 2,4-D at 16 oz/A, dicamba at 24 oz/A and picloram at 8 and 12 oz/A. A significant reduction in germination also occurred in seed harvested from the 8 and 12 oz/A picloram plots in 1970 (Table 12). Reductions, though significant, in no case exceeded 10 per cent.

Small but significant reductions in the germination of timothy seed harvested from plots at Spedden in 1970 resulted from 16 and 24 oz/A of dicamba (Table 12). Seedlings from such seed exhibited no visible treatment effects at any time.

There were indications that growth stages at which herbicides are applied could be an important factor to consider (Table 13). Germination of timothy seed was generally reduced to a greater extent when herbicides were applied during the two earlier growth stages than at the post-flowering stage.

Dicamba treatments applied at the two-weeks post-flowering stage did not significantly reduce timothy seed germination but did cause severe shoot bending of seedlings. Picloram at 2 oz/A did not

Table 12 Germination percentages of creeping red fescue seed harvested from Peoria in 1969 and 1970 and timothy seed harvested from Spedden in 1970.

| Treatment | Peoria 1969 | Peoria 1970 | Spedden 1970 |
|---|---|---|---|
| Check | 96.5* ab | 92.5*ab | 86.3**ab |
| 2,4-D, 16 oz/A | 87.5 d | 91.5 ab | 85.3 ab |
| Picloram, 2 oz/A | 97.0 ab | 96.5 a | 89.0 ab |
| Picloram, 4 oz/A | 98.5 a | 94.0 ab | 90.0 a |
| Picloram, 8 oz/A | 92.5 bc | 87.5 bc | 84.3 ab |
| Picloram, 12 oz/A | 93.5 bc | 83.5 c | 86.5 ab |
| Dicamba, 8 oz/A | 96.0 ab | 97.0 a | 87.5 ab |
| Dicamba, 16 oz/A | 96.5 ab | 92.5 ab | 83.3 b |
| Dicamba, 24 oz/A | 90.5 cd | 94.0 ab | 78.0 c |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test.

* Means of two replicates.

** Means of four replicates.

Table 13 Germination percentages of timothy seed harvested from plots at Bezanson in 1970.

| Treatment | Percentage germination Stage 1 | Stage 2 | Stage 3 |
|---|---|---|---|
| Check | 89.0 ab | | |
| 2,4-D, 16 oz/A | 81.5 cdef | 85.5 abcdef | 86.8 abcdef |
| Picloram, 2 oz/A | 87.3 abcde | 90.3 a | 87.5 abcde |
| Picloram, 4 oz/A | 87.8 abcd | 79.8 f | 82.3 bcdef |
| Picloram, 8 oz/A | 80.8 def | 80.5 def | 80.5 ef |
| Picloram, 12 oz/A | 80.1 f | 80.5 ef | 84.0 abcdef |
| Dicamba, 8 oz/A | | | 85.0 abcdef |
| Dicamba, 16 oz/A | | | 85.5 abcdef |
| Dicamba, 24 oz/A | | | 88.0 abc |

Means followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test. All data are means of four replicates.

Growth stages at treatment time were;

Stage 1: 3 to 4 leaves per tiller, May 20, 1970

Stage 2: 5 to 7 leaves per tiller, June 1, 1970

Stage 3: Two weeks following the peak bloom period, July 21, 1970.

reduce timothy seed germination at any stage of growth. Higher rates resulted in inconsistent germination percentages. Dicamba treatments which were applied at the two earliest growth stages of timothy reduced seed yields to the extent that germination tests were considered unnecessary in these cases.

The reductions in germination of the seed harvested in 1969 and 1970 from the plots treated with 8 and 12 oz/A of picloram or 16 and 24 oz/A of dicamba was attributed to the delay in maturity of the grass crops. Other workers have reported reductions in seed germination of these crops (4,50,78). Yarish et al.(78) reported that reductions in germination of creeping red fescue seed from plants treated with 4 to 6 oz/A of picloram would occur when applied under lush growing conditions.

Wherever drastic yield reductions occurred there usually was a corresponding reduction in germination. The significant reductions in germination were in no case more than 9.4 per cent below that of the untreated check seed germinations. If 10 per cent of a grass seed field was treated, even the most severe germination reduction reported in this investigation would result in less than a one per cent reduction in germination of the seed harvested from the field. Therefore, the importance of seed germination when herbicides are applied on a spot application basis is questionable unless seedlings show serious symptoms of herbicide injury.

2. Greenhouse Experiments

A. Tolerance of Grasses to Soil-Applied Herbicides.

Germination of grass seed was unaffected by herbicide treatments but in pots treated with 16 and 24 oz/A of dicamba and 12 oz/A of picloram a number of seedlings died within 8 days after emergence.

Dicamba (8,16, and 24 oz/A) and picloram (4,8, and 12 oz/A) treatments caused bending and prostration of grass shoots. The response of timothy to 4 oz/A of picloram sprayed on the soil surface and then mixed with the soil to a depth of 2.5 to 3.0 inches prior to seeding is illustrated in Figure 5 (lower). A corresponding untreated pot is shown in Figure 5 (upper). Injury symptoms remained visible on plants for at least 7 weeks.

Timothy survival was not significantly reduced by 2 oz/A of picloram (Table 14a). All dicamba treatments and picloram at 8 and 12 oz/A were the most inhibitory to survival. Creeping red fescue displayed more tolerance to herbicides; plant survival was not significantly reduced by 16 oz/A of 2,4-D, or by picloram at 2 and 4 oz/A. Creeping red fescue but not timothy showed a significant increase in survival when herbicides were worked into the top 2.5 to 3.0 inches of soil. This response is likely a result of diluting the herbicides in the surface layer of the soil. These results cannot be directly compared with those of Arnold (2), but they do demonstrate that wide differences in survival capabilities do exist between grass species.

Dry matter production of timothy plants was not significantly reduced by 16 oz/A of 2,4-D and 2 or 4 oz/A of picloram. A cultivation to a depth of 2.5 to 3.0 inches following treatment and prior to seeding significantly increased timothy and fescue dry matter production (Table 14b).

Although creeping red fescue seedlings survived the soil treatments better than timothy, further plant growth was more adversely affected. Except for 2,4-D at 16 oz/A, all treatments significantly

Figure 5. Comparison of the effects of pre-planting herbicide treatments on the survival of timothy. Upper: no herbicide, cultivated. Lower: picloram at 4 oz/A, cultivated.

Table 14a Effect of pre-plant herbicide and cultivation treatments on the survival of timothy and creeping red fescue under greenhouse conditions

| Treatment | Plants per pot, 32 days after seeding | | | | | |
|---|---|---|---|---|---|---|
| | Timothy | | | Creeping red fescue | | |
| | Cultivated | Not Cultivated | Mean | Cultivated | Not Cultivated | Mean |
| Check | 30.3* | 33.5* | 31.9a** | 34.3* | 31.5* | 32.9a** |
| 2,4-D, 16 oz/A | 21.8 | 12.3 | 17.0bc | 33.3 | 28.5 | 30.9a |
| Picloram, 2 oz/A | 27.0 | 12.5 | 19.8ab | 32.8 | 21.0 | 26.9ab |
| Picloram, 4 oz/A | 25.8 | 4.5 | 15.1bc | 32.0 | 13.3 | 22.6ab |
| Picloram, 8 oz/A | 8.8 | 1.3 | 5.0cd | 25.5 | 8.0 | 16.8bc |
| Picloram, 12 oz/A | 0.3 | 0.0 | 0.2d | 16.8 | 4.0 | 10.4cd |
| Dicamba, 8 oz/A | 0.8 | 0.0 | 0.4d | 11.5 | 0.5 | 6.0cd |
| Dicamba, 16 oz/A | 0.0 | 0.0 | 0.0d | 1.8 | 0.0 | 0.9d |
| Dicamba, 24 oz/A | 0.0 | 0.0 | 0.0d | 2.0 | 0.0 | 1.0d |
| | 12.7†f‡ | 7.1f | | 21.1†f‡ | 11.9g | |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test.

* Mean of four pots.
** Mean of eight pots; cultivated and not cultivated data are combined for each herbicide treatment

† Mean of thirty-six pots; herbicide treatment data are combined for each cultivation treatment.

‡ Statistical significance determined by the F-test.

Table 14b Effect of pre-plant herbicide and cultivation treatments on the dry matter production of timothy and creeping red fescue under greenhouse conditions.

| Treatment | Dry matter, grams per pot | | | | | |
|---|---|---|---|---|---|---|
| | Timothy | | | Creeping red fescue | | |
| | Cultivated | Not Cultivated | Mean | Cultivated | Not Cultivated | Mean |
| Check | 11.9* | 11.9* | 11.9a** | 7.1* | 7.2* | 7.1a** |
| 2,4-D, 16 oz/A | 11.1 | 9.5 | 10.3a | 7.6 | 5.6 | 6.6ab |
| Picloram, 2 oz/A | 11.2 | 11.5 | 11.3a | 6.5 | 5.1 | 5.8bc |
| Picloram, 4 oz/A | 11.5 | 7.4 | 9.5a | 5.8 | 4.2 | 5.0c |
| Picloram, 8 oz/A | 7.6 | 2.7 | 5.2b | 3.6 | 1.9 | 2.7d |
| Picloram, 12 oz/A | 0.0 | 0.0 | 0.0c | 2.5 | 1.0 | 1.7d |
| Dicamba, 8 oz/A | 4.0 | 0.0 | 2.0c | 3.6 | 0.0 | 1.8d |
| Dicamba, 16 oz/A | 0.0 | 0.0 | 0.0c | 0.2 | 0.0 | 0.1e |
| Dicamba, 24 oz/A | 0.0 | 0.0 | 0.0c | 0.0 | 0.0 | 0.0e |
| | 6.4†f‡ | 4.8g | | 4.1†f‡ | 2.7g | |

Means in the same column followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test.

* Mean of four pots.

** Mean of eight pots cultivated and not cultivated data are combined for each herbicide treatment.

† Mean of thirty-six pots, herbicide treatment data are combined for each cultivation treatment.

‡ Statistical significance determined by the F-test.

reduced dry matter production of creeping red fescue. The cultivation treatment here also resulted in a significantly smaller reduction in dry matter production caused by the herbicides.

The results in Table 14b support the suggestion that established grass seedlings of different species can differ widely in their ability to grow and develop in the presence of persistent herbicides such as dicamba and particularly picloram.

B. Tolerance of Grasses to Foliar-Applied Herbicides at Three Growth Stages

Only dicamba at 16 oz/A significantly reduced timothy dry matter production below that in other treatments (Table 15). There was no significant difference between means of growth stages, though there was a trend towards increased dry matter production with later treatments of picloram at 8 oz/A and dicamba at 16 oz/A.

Picloram at 8 oz/A and dicamba at 16 oz/A significantly reduced creeping red fescue dry matter production below that in other treatments (Table 15). The data suggest that creeping red fescue was more sensitive at the 3- to 4- leaf stage than at later stages of growth, but this difference was not significant. The suggestion was further supported, however, by a trend towards higher dry matter production of creeping red fescue with later applications of picloram at 4 oz/A and dicamba at 8 oz/A.

On July 27, 1970, creeping red fescue plants exhibited symptoms of prostrateness, leaf kinking, and bending of young tillers from all treatments. Picloram at 8 oz/A and dicamba at 16 oz/A caused the most severe effects, particularly following treatments at the earliest growth stage. Symptoms resulting from later treatments were less severe.

Table 15 Effect of post-emergent herbicide treatments applied at three growth stages on dry matter production of timothy and creeping red fescue under greenhouse conditions.

| | Dry matter, gm per pot | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Timothy | | | | Creeping red fescue | | | |
| Treatment | Stage 1 | Stage 2 | Stage 3 | Mean | Stage 1 | Stage 2 | Stage 3 | Mean |
| 2,4-D, 16 oz/A | 7.0* | 5.8* | 5.8* | 6.2a** | 5.3* | 4.8* | 5.3* | 5.1ab** |
| Picloram, 4 oz/A | 6.4 | 6.1 | 7.5 | 6.7a | 4.9 | 5.8 | 6.1 | 5.6a |
| Picloram, 8 oz/A | 5.6 | 6.0 | 7.1 | 6.2a | 4.2 | 5.0 | 4.2 | 4.5bc |
| Dicamba, 8 oz/A | 6.6 | 6.0 | 5.9 | 6.1a | 5.3 | 6.0 | 6.1 | 5.8a |
| Dicamba, 16 oz/A | 4.7 | 5.1 | 5.2 | 5.0b | 2.3 | 5.2 | 4.0 | 3.8c |
| | 6.0[a]d | 5.8d | 6.3d | | 4.4[a]d | 5.4d | 5.1d | |

Means in the same column or row followed by the same letter are not significantly different from each other at the 5% level of probability as determined by Duncan's new multiple range test.

* Mean of four pots.
** Mean of twelve pots; data for the three growth stages were combined for each herbicide treatment.

Growth stages at treatment time were;

Stage 1: 3 to 4 leaves per tiller.

Stage 2: 1 to 3 tillers per plant.

Stage 3: 3 to 6 tillers per plant.

[a] Mean of twenty pots; herbicide treatment data are combined for each growth stage.

Timothy responded with the same symptoms and, in addition, tip die-back of leaves occurred on plants treated with picloram at 8 oz/A and dicamba at 8 and 16 oz/A.

Prior to clipping the grasses for dry matter determinations on September 24, 1970, pots in each treatment were grouped and examined for visible treatment effects. Symptoms of herbicide injury were only slight in most cases. The number of tillers per plant of creeping red fescue was increased by 2,4-D applied at all growth stages and this increase was most noticeable where the herbicide was applied at the 3- to 4- leaf stage. Picloram treatment effects varied. The 4 oz/A rate caused little effect but the 8 oz/A rate resulted in pronounced prostrateness and bending of young fescue tillers. Dicamba at 8 oz/A caused slight effects but the 16 oz/A rate resulted in obvious symptoms of prostration and bending of the young tillers.

Timothy did not exhibit definite injury symptoms due to treatment. Only the 16 oz/A rate of dicamba caused visible reductions in growth.

Creeping red fescue stands were not affected with the exception of one seedling treated with 16 oz/A of dicamba at the 3- to 4- leaf stage. Timothy, on the other hand, was more sensitive at the 3- to 4- leaf stage and the 1- to 3- tiller stage than at the 3- to 6- tiller stage (Table 16). These results suggest that timothy was more sensitive to dicamba than to picloram or 2,4-D at the rates used in this study.

The results of this section support the suggestion that grass susceptibility to most herbicides decreases with age and development of the grass plant (2,10,12,13,60).

Table 16 Seedling mortality after post-emergent herbicide treatment of timothy at different growth stages under greenhouse conditions.

| Treatment | Number of dead plants<br>Stage 1 | Stage 2 | Stage 3 | Total |
|---|---|---|---|---|
| 2,4-D, 16 oz/A | 1* | 1 | 0 | 2 |
| Picloram, 4 oz/A | 0 | 0 | 0 | 0 |
| Picloram, 8 oz/A | 0 | 1 | 0 | 1 |
| Dicamba, 8 oz/A | 2 | 2 | 0 | 4 |
| Dicamba, 16 oz/A | 4 | 2 | 1 | 7 |
| Total | 7 | 6 | 1 | |

Growth stages at treatment time were;

Stage 1: 3 to 4 leaves per plant.

Stage 2: 1 to 3 tillers per plant.

Stage 3: 3 to 6 tillers per plant.

* Number of dead plants out of twelve for each treatment at each growth stage.

3. Soil Bioassay of Herbicide Residues

Throughout this set of experiments, a standard concentration series (Figure 6) was used to estimate the concentration of phytotoxic residues remaining in the soil treated with a herbicide at a particular plot site. Figure 6 illustrates the injury symptoms resulting on cucumber plants grown in soil with a standard concentration series of picloram. The first visible injury symptoms (slight cupping of leaf margins) occurred at a soil concentration of .003 ppmw in the Peoria soil (Figure 7). These injury symptoms were consistent throughout the bioassays but the concentration of herbicide required to cause visible injury symptoms varied with the soil organic matter content (Table 17). These detection characteristics were also displayed by dicamba. The St. Albert soil permitted the detection of dicamba at .243 ppmw and the other soils permitted detection at .081 ppmw.

Bioassay of soil samples from dicamba-treated plots indicated no detectable residue after one growing season. Results from Ellerslie and Legal plots suggest that one growing season with suitable moisture and temperature conditions is necessary before grasses can be established on soil previously treated with 1.5 to 2.0 lb/A of dicamba. Reports by others (1,55) support this suggestion.

The only location at which any appreciable disappearance of picloram occurred was St. Albert (Table 17). No phytotoxic residues were detected in plots treated with picloram at 2 and 4 oz/A. Plots treated with 8 and 12 oz/A of picloram displayed lower phytotoxic residues than were detected at other locations. Phytotoxic residues of picloram detected at Legal and Warspite were somewhat less than those

Figure 6. Typical standard concentration series for picloram soil residue determinations. Soil concentrations of picloram (oven dry basis) from left to right are: .729, .283, .081, .027, .009, .003 ppmw and no treatment. Soil was taken from untreated plots at Peoria.

Figure 7. Cucumber injury symptoms caused by a .003 ppmw soil concentration (oven dry basis) of picloram on the left. Plants on right grown in untreated soil. Plants are part of the standard concentration series illustrated in Figure 6.

Table 17 Residues of picloram detected in soil samples from plots at various Northern Alberta locations.

| Location | Treatment Date | Sampling Date | Soil Analysis* %O.M. | %Clay | %Silt | %Sand | (PPMW) Detection Limit of Herbicide** | Soil Residues Detected 2 oz/A | 4 oz/A | 8 oz/A | 12 oz/A | 16 oz/A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Peoria | 6-21-69 | 8-17-70 | 3.2 | 19 | 42 | 39 | .003 | <.009 | <.027 | .081 | <.243 | |
| St. Albert | 8- 7-69 | 10-10-70 | 10.9 | 50 | 25 | 25 | .027 | ND | ND | .027 | <.081 | |
| Legal | 8-22-69 | 10- 3-70 | 5.4 | 24 | 46 | 30 | .009 | | <.027 | <.081 | .081 | <.243 |
| Warspite | 9-28-69 | 10- 4-70 | 4.8 | 22 | 25 | 53 | .009 | <.009 | <.027 | <.081 | >.081 | |
| Spedden | 9-28-69 | 8-26-70 | 6.8 | 7 | 37 | 56 | .009 | .009 | <.027 | >.081 | .243 | |
| Ellerslie | 5-12-70 | 10- 2-70 | 8.8 | 29 | 28 | 43 | .009 | .009 | <.027 | .081 | .243 | |

* Soil textural sizes according to the U.S.D.A. particle size classification.

** Detection limit is the lowest herbicide concentration in the standard series which caused visible injury symptoms on the test plants.

ND: No detectable herbicide residue.

detected at the remaining locations, Spedden, Ellerslie, and Peoria.

The relatively rapid disappearance of picloram at St. Albert can be attributed to the high organic matter content of this soil (10.9 per cent). Soil organic matter not only reduces the phytotoxic effect of soil-applied picloram through adsorption but also increases the rate of dissipation of picloram by the enhancement of microbial activity (28,37,66,70). This was particularly evident when residues at St. Albert were compared with those at Peoria where phytotoxic picloram residues were still relatively high. The organic matter content of the Peoria soil was 3.2 per cent.

Phytotoxic residues from 8 oz/A applications of picloram can be expected to remain in most soils in Alberta for some time. Vanden Born (76) reports that 12 per cent of the original picloram dosage of 1.44 and 2.88 lb/A was detected four years following application. Four and one half years following treatment sunflower and alfalfa were safely established. The soil type on which that study was conducted was in the same locality as that of the Ellerslie plot in the present investigation. This soil had an organic matter content of 8.8 per cent (Table 17).

The rates of picloram applied in Vanden Born's investigation were at least double those used in the present study. Therefore, if 4 to 8 oz/A of picloram were applied prior to the seeding of a crop of either grass species and the land remained in production for three to four years, little if any phytotoxic soil residues of picloram would remain in a soil containing six or more per cent organic matter. During this period precipitation and temperatures would of necessity have to be near "normal" for Northern Alberta in order that the detoxification

process would progress in the expected manner.

# SUMMARY AND CONCLUSIONS

Several approaches were used in order to gather pertinent information regarding the feasibility of using two herbicides viz. - dicamba and picloram, for the control of Canada thistle in grass seed crops.

Picloram was the most effective herbicide for thistle control, followed by dicamba and then 2,4-D. Plant competition and cultivation following treatment were found to substantially increase the effectiveness of these herbicides. The particular ecotype or strain of thistle was important also. Additional repeat applications with picloram and dicamba at reduced rates would be expected to enhance the effectiveness of the initial herbicide treatment and at the same time good crop tolerance could be retained.

Crop sensitivity of the two grass species to the three herbicides was not found to be a major barrier to their use. A problem becomes obvious when one considers the possibility that highly susceptible crops such as alfalfa and various clovers may follow grass seed crops as part of a crop rotation program. Low rates (2 to 4 oz/A) of picloram in most cases result in detectable phytotoxic residues remaining in the soil for more than one and one-half growing seasons and these would pose difficulties when establishing such crops.

Herbicide tolerance of the individual grass species differs in an unusual manner. On a pre-emergence treatment basis the larger-seeded creeping red fescue is better able to germinate and emerge as opposed to the smaller-seeded timothy which suffered stand reductions. Once established though, the more rapid growing timothy tolerated the

herbicide residues, particularly those of picloram, better than the creeping red fescue.

In the field, both grass species will tolerate low rates (2 to 4 oz/A) of picloram applied at almost any chosen growth stage. Dicamba, at the rates used in this study, will not be tolerated in most cases. The low rate of dicamba (8 oz/A) will be comparatively well tolerated on a post-harvest basis in the fall of the crop year.

Herbicide effects one year following treatment with picloram may be related to the induction and initiation requirement of the grass species. Creeping red fescue has relatively specific requirements and is more sensitive to the herbicide while timothy has less specific requirements and was much more tolerant to the herbicide.

Grasses benefited from thistle control in that tiller numbers per plant increased substantially. If a large part of the acreage is infested (10 - 20%) then tangible increases in seed yields can be expected from effective control treatments. The herbicides picloram and dicamba are relatively expensive in terms of cost per ounce of acid at the retail level, $1.75/ounce and $0.50/ounce of acid respectively. These can be compared with 2,4-D at $0.07/ounce of acid which essentially provided no control. Four ounces per acre of picloram, although marginal, gave reasonable results compared to all other treatments. This would cost the grower about $7.00 per acre plus the additional costs of application. Dicamba at 24 oz/A would cost the grower about $12.00 per acre plus the cost of application.

Stopping in the field or turning short corners would result in undesirable "spots" where the application rate could be several times that in the remainder of the field. This could produce spots in the

field being non-productive for susceptible crops for a prolonged period of time.

In conclusion, an outline of a possible procedure for the chemical control of thistles in creeping red fescue and timothy seed crops as indicated by the results from this study and Provincial recommendations follow:

1. Apply picloram at 4 - 8 oz/A or dicamba at 24 - 32 oz/A on a spot application basis, to thistles which are in the bud stage and actively growing, before seeding the grass crop.
2. Cultivate the field or spots where the herbicide was applied, 3 to 4 weeks after treatment and continue cultivation for the remainder of the season every 21 to 28 days.
3. Delay the seeding of grasses until the following year and increase the seeding rate by 15 to 25 per cent above normal seeding rates where treatments are applied.
4. Treat annual broadleaf weeds and Canada thistle regrowth in the year of seeding with a mixture of 4 oz/A of dicamba and 8 to 10 oz/A of MCPA (2-methyl-4-chlorophenoxy acetic acid) amine or 2,4-D amine when timothy and creeping red fescue seedlings are past the 3 - 4 leaf stage.
5. Spray thistles in the seed production years with 8 oz/A of MCPA amine or 2,4-D amine before the crop has reached the boot stage or when 25 per cent of the seeds are in the hard dough stage.

6. Avoid plowing of the treated area, and seeding to a different crop for three to four years following treatment, to ensure that no phytotoxic picloram residues remain.

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